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ABSTRACT

A 2-part investigation was conducted to examine the ways children resolve the inherent ambiguity of spatial descriptions in terms of cues indicated by the three constituents of spatial propositions: predicate, referent, and relatum. In the first study, it was hypothesized that certain objects, structural markers, and definite articles accompanying the predicate would increase the incidence of intrinsic object-related interpretations of spatial descriptions. A total of 30 male and 30 female subjects participated in the study. Of these, 45 were nursery school children in three age groups (mean ages of 3.3, 4.5, and 6r.5 years). Participating adults ranged in age from 19 to 62 years. Tasks included two verbal items to assess the use of definiteness in linguistic referencing and 24 items to examine the interpretations of ambiguous spatial descriptions. Findings indicated that, in contrast to the other groups, young children's interpretations of spatial locatives rely most heavily on the intrinsic features of the objects being manipulated. Although the 5-year-olds' responses were different from those of the two younger groups, their performance was not like that of adults. Accordingly, a second study was conducted to follow changes across the next 2 years. Mean ages of the 23 males and 22 females assigned to three age groups were 5.6, 6.9, and 7.9. Different cues were found to be relevant for the different ages examined. The 5-year-olds responded according to the object and the marker, while the 6- and 7-year-olds responded according to the presence of the definite article in the predicate. (RH)

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Resolving Ambiguity From Competing Spatial Frames of Reference

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The ambiguity of spatial relations is not usually a source of difficulty in interpreting language in context. Yet the reliability with which adults interpret spatial expressions that are inherently ambiguous is surprising when one considers the range of possible interpretations. Adults tend to agree, for example, where the "top" of an object is irrespective of its orientation, and irrespective of its possession of an intrinsically marked top. In deciding on an interpretation adults appear to base these judgments on a number of features of the linguistic expression. But how do children interpret ambiguous spatial descriptions? Do they notice the ambiguity? And do their resolutions rely upon the same features as do those of adults? These are the questions addressed in the present study.

The representation of spatial relations is assumed to be based on a propositional structure that is assigned to a display, having the form :

predicate(referent,relatum).

This formalism, adopted from Miller and Johnson-Laird (1976), identifies three critical features of a spatial description. The referent is the object being related (or located in space), the subject of the sentence in natural language, and as such, is essentially unbounded. The relatum is the frame of reference from which the expression is constructed. Spatial descriptions, being relational, must be

specific to a point of view, which in the present notation, is given by the relatum. Further, the possible relata for spatial expressions can be considered in terms of about four categories - egos, objects, observers, and environments. Finally, the predicate is the spatial concept that describes the relationship between the referent and the relatum. In language, these are the terms of the spatial lexicon, but the spatial predicates are by no means confined to those concepts which are explicitly marked in language. Elsewhere, Olson and Bialystok (1983) have illustrated the ways in which these three constituents of the proposition are involved in the representation of spatial displays and the transformation of spatial descriptions in problem solving by both children and adults.

The problem of ambiguity arises when the relatum of the spatial expression is a featured object which is misaligned from its normal orientation, since the reference frame may be interpreted either in terms of the intrinsic features of the object (object relatum), or the location of that object in space (environmental or ego relatum) (Clark, 1973; Harris, 1977; Miller & Johnson-Laird, 1976; Rock, 1973; Rosser, 1983). The propositional expression for "Stand in front of the house", for example, takes the form:

in front(you, house).

If the internal structure of the house (object relatum) defines the meaning, then the designated location is at the front door; if the position of the house relative to the speaker is considered (ego relatum), then the designated position is the side nearest the speaker, even if it is in the back yard. The relatum itself, the house, has not changed, but the function of that relatum in terms of the interpretive categories, that is, object or ego, has changed, and that change results in a different solution to the sentence meaning.

This described ambiguity, while most obvious in the featured object, is also observed in the unfeatured object. Hill (1978), in a cross-cultural study, found that in some cultures adults would select front as a position which corresponded to the direction they were facing, that is by choosing a position as if the unfeatured object was in a tandem position with them where its front was on the opposite side to that which faced them. Adults from a western culture were more likely to select front as the side which faced them. Within groups the selection is remarkably consistent. Similarly, Abkarian (1982) found the most inconsistency amongst adults responses to non-featured items in placements of 'in front'.

Since adults do not usually get confused about such sentences, there are undoubtedly conventional means for di-

sambiguation. The three possible sources of disambiguation are the three constituents of the proposition, that is, the predicate, the referent, and the relatum. The hypothesis is that each of these constituents contribute to the interpretation of the spatial expression in that typical values are assigned to each. Thus, the interpretation of a description such as "Stand in front of the house" depends upon an evaluation of each of the three terms in the proposition. To what extent, then, do children systematically use these three sources of information to interpret spatial descriptions?

The development of the ability to use different types of relata, specifically allocentric (object or observer) and egocentric (ego or environment) has been studied by a number of researchers. A basic claim often made is that these two perspectives are ordered, in that the egocentric one is acquired prior to the allocentric one (Acredolo, 1981; Kuczaj & Maratsos, 1975). Operationally, this is what Piaget and Inhelder (1956) mean by 'egocentrism'; and development in their terms involves gradually 'decentering' in order to use the allocentric alternative. Miller and Johnson-Laird (1976) concur with Cassirer (1923) that the "conceptual core of space originates with the body concept" (Miller & Johnson-Laird, 1976, p.394). They go on to argue, however, that there is no evidence that one of these two perspectives,

which they call deictic and intrinsic, is actually mastered first. Others, too, have distinguished these two perspectives without committing themselves to the developmental primacy of the egocentric code (Braine & Eder, 1983; Harris, 1977; Tanz, 1980). In these accounts, the mature problem-solver is able to accommodate both as viable alternatives. Some problems, in fact, appear to be solved by children in terms of an allocentric object code where adults would ordinarily use an ego code (Bryant, 1974).

Little evidence is available on developmental changes in children's interpretation of ambiguous allocentric expressions. Some studies show children using the object-related code prior to the ego-related code to find the front of featured objects, but these studies tended to ignore the ambiguity and considered unexpected responses as errors (Clark, 1980; Kuczaj & Maratsos, 1975; Levine & Carey, 1982). Other evidence, however, suggests that children's interpretations of objects in the world are probably at least as much governed by their experiences with those objects as by their abstract knowledge of structure (e.g., E. Clark, 1973). Thus it may be that whether the child decides that the top of an object is at the intrinsic top or at an environmentally-determined spatial top may well depend upon what the object is and what orientations and experiences the child associates with that object. Spatial ambiguity in

terms of the relatum, then, may be resolved by children pragmatically.

The referent of a spatial expression may also be relevant to assigning a meaning. The referent can specify one of two kinds of spatial descriptions - structural, in which the referent is a part of the relatum (the eyes are at the top of the head), or relational, in which the referent is another object related to the relatum (the hat is on top of the head) (Olson & Bialystok, 1983). This difference biases the interpretation of the relatum. For a structural display, the relatum is more likely to be considered in terms of its intrinsic properties, making it function as an object-related description; for a relational display, the relatum is more likely to be considered in terms of its spatial properties, making it function as an environmental-related description. Adults have been shown to adjust their interpretations in just this way when the referent of an expression changed from an adhesive marker placed in relation to an inverted cup, and a toy animal placed in the same position with respect to the cup (Bialystok, 1976). In the first case, the marker was described as being "on the bottom of the cup" while the animal was "on top of the cup". The marker referent entered into a structural relation with the cup and biased the interpretation of the relatum towards the object-related description.

Finally, the predicate too influences the interpretation of the spatial proposition. One linguistic feature used by adults is the use of definite or indefinite reference as it accompanies the spatial predicate. The definite article indicates that the spatial feature intrinsic to the object is the intended meaning (Clark, 1973; Olson & Bialystok, 1983; Talmy, 1983; Tanz, 1980; Wood, 1967). The presence of the definite article transforms the predicate from a preposition to a noun with the effect being to make spatial descriptions containing definite articles in the predicate essentially structural, rather than relational. While children appear to have mastered the definite-indefinite distinction in verbal contexts by about three years old (Brown, 1973; Dunlea, 1978; Karmiloff-Smith, 1976; Macnamara, 1982; Maratsos, 1976), it is not clear whether or not they apply this distinction to spatial predicates to disambiguate complex descriptions.

In sum, the three constituents of the spatial proposition each contribute to the meaning of the description in cases in which a featured object is the relatum and the space defined by the structure of that object conflicts with the space defined by its location. The present study is an examination of the way in which children resolve the inherent ambiguity in terms of the cues indicated by these three constituents. Children and adults are compared for the way

in which they locate objects with respect to another in instructions containing predicates that include definite or indefinite articles, for referents that are either nondescript markers or real objects, from the point of view of relata that are featured objects of different kinds. The hypothesis is that certain objects, structural markers, and definite articles accompanying the predicate, will increase the incidence of intrinsic object-related interpretations of spatial descriptions.

STUDY 1

Method

Subjects

There were 60 subjects in the study, 30 female, and 30 male. Of these, 45 were nursery school children divided into three groups of fifteen according to age. The mean age per group was 3.3, 4.5, and 5.5 respectively. All children spoke English as their first language. Adults were 15 subjects ranging in age from 19 to 62 years. The distribution of male and female subjects within each groups was roughly equivalent.

Apparatus

The apparatus consisted of three featured objects to serve as relata with clearly distinguishable tops, bottoms, fronts, and backs. An inanimate but characteristically mo-

bile object was represented by a brightly coloured toy car. An animate nonhuman object was a toy cow which stood on all four legs. A human-like object was represented by a bright green muppet doll.

The referent markers consisted of a red three-dimensional free standing star and a bright green 3/4 inch diameter adhesive dots.

Design

The tasks included two verbal items to assess the use of definiteness in linguistic referencing and 24 items to examine the interpretations of ambiguous spatial descriptions.

The two verbal items were two stories selected from the Maratsos (1976) study. The stories had both a definite and indefinite version and story-definiteness pairings were counterbalanced. Thus, each subject was administered one story in the definite version and the other in the indefinite, comprising two stories altogether.

The spatial items were created by generating all combinations of the factors referent, relatum, predicate, for two spatial concepts, front and top.

Procedures

Subjects were asked to listen to each verbal instruction and create the described pattern using the set of ma-

terials given. An example, such as "Put the star on top of the car" was given. The orientation in which each of the object relata was presented was calculated to maximize the conflicting interpretations. For all questions, the objects were oriented so that an intrinsic side of the object, rather than the front or the back, faced the child. For questions involving "tops", the car and cow were positioned lying on their sides and the doll lying on its back; for questions involving "fronts", these objects were positioned upright. Responses were coded as intrinsic (object-related), if the structure of the object was used to determine the location, and extrinsic (ego or environment-related), if the spatial orientation was used, and error, if neither formed the basis of the response. The data for analyses were the number of intrinsic responses elicited by each item.

Results

In the story test of article use the mean score out of 1 per group was .700 for the 3-year-olds, .800 for the 4-year-olds and .7667 for the 5-year olds and .833 for the adults. These scores show no significant differences among age groups in the sensitivity of definiteness as a linguistic marker $F(3,56) < 1.0$.

In the spatial placement task analyses were performed on the proportion of intrinsic responses to each item across age groups. Data from 'front' and 'top' placement tasks were treated separately.

All subjects responded similarly for the 'front' placement task. With few exceptions the front of the object was always interpreted by its intrinsic properties. There were no differences in performance between groups for this task.

A repeated measures three-way analysis of variance for the 'tops' spatial task showed main effects for object $F(2,112) = 29.91$, $p<.0001$, article $F(1,56) = 14.33$, $p<.0001$, and marker $F(1,56) = 13.18$, $p<.001$. The mean proportion of intrinsic responses for 'tops' instructions by Age X Marker X Article are illustrated in Figures 1 and 2. The 3-year-old group is the only group which committed placement errors.

Significant interactions were found between age and marker $F(3,56) = 5.27$, $p<.003$, (Figure 1) and between age and article $F(3,56) = 7.45$, $p<.0001$ (Figure 2).

These effects were examined more closely by an analysis of simple effects with age held constant. In this first analysis object was significant for the 3, 4 and 5-year-olds but not for the adults. Using the Greenhouse-Geisser conservative F test, which yields adjusted degrees of freedom, significance was found for the following groups: three-

year-olds $F(1.84,103.19) = 7.14$, $p<.001$, four-year-olds $F(1.84,103.19) = 7.35$, $p<.001$, and five-year-olds $F(1.84,103.19) = 11.20$ $p<.0001$. Simple effects analysis at each age group showed marker to be significant only for the five-year-olds $F(1,56) = 24.51$, $p<.00001$, where there were more intrinsic placements with the dots. Article was only found to be significant for adults $F(1,56) = 35.13$, $p<.00001$, the effect being an increase in intrinsic placements for the instructions containing the definite article.

Discussion

The spatial placement tasks of 'front' and 'top' were treated quite differently. While 'front' was nearly always interpreted as intrinsic 'top' was evaluated differently across the items.

The most influential factor was the object itself with the car providing the most compelling features to produce object-related responses. The doll exerted the least influence on object-related responses with the cow inducing a moderate influence. Thus, consistent with previous research (Clark, 1980), young children's interpretations of spatial locatives relies most heavily on the intrinsic features of the objects being manipulated. The object relatum is most salient in this regard, while sensitivity to the object referent emerges a little later. Only the five-year-olds

adjusted their interpretations when the referent marker was changed from a three-dimensional star to an adhesive dot, the latter producing more intrinsic responses.

Although performance on the verbal task for the definite article was equivalent to older children and adults the two youngest groups (3 and 4-year olds) did not use that feature to determine appropriate placements. The adult group relied most consistently on the presence of the definite article to decide upon a placement that satisfies the description given in the instruction.

Although the 5-year-olds were responding differently from the two younger groups, their performance was still not adult-like. Accordingly, a second study was conducted to follow these changes across the next two years.

STUDY 2

Method

Subjects

There were 45 subjects in Study 2, 23 males and 22 females. All were attending a public school in downtown Toronto. Subjects were divided into three age groups of fifteen according to age. The mean age per group was 5.6, 6.9 and 7.9. All subjects first language was English. The distribution of male and female subjects within each group was roughly equivalent.

Design and Procedure

The same materials and procedures used in Study 1 were used again in Study 2.

Results

The mean score per group for the story test of article use, out of a possible score of one, was .700 for the 5-year-olds, .857 for the 6-year-olds and .733 for the 7-year-olds $F(2,41) < 1.0$.

A three-way repeated measures analysis of variance for the number of intrinsic placements in the 'tops' spatial task showed main effects only for article $F(1,42) = 28.90$, $p < .0001$. There were no main effects for object or marker.

A significant interaction was found between age and article $F(2,42) = 7.27$, $p < .002$ (Figure 2).

An analysis of simple effects was carried out on the interaction. The simple effects analysis for object (using the Greenhouse-Geisser conservative F test with adjusted degrees of freedom) revealed that only the 5-year-olds adjusted their proportion of intrinsic responses according to object. $F(1.84,77.31) = 3.33$, $p < .04$. Marker was also found significant only for the 5-year-olds $F(1,42) = 9.48$, $p < .003$ (Figure 1). Simple effects of article found that both the 6-year-olds $F(1,42) = 9.44$, $p < .003$, and the 7-year-olds, $F(1,42) = 28.90$, $p < .0001$, adjusted their response according to article.

Discussion

As with Study 1, different cues were found to be relevant for the different ages examined. The 5-year-olds determined their placements according to the object and the marker, the 6 and 7-year-olds, according to the presence of the definite article in the predicate. Thus, it is not until 6-years-old that children use this linguistic feature in the way adults do to resolve spatial ambiguity, even though their use of the feature in verbal contexts is mastered by 3-year-olds.

General Discussion

The two studies while carried out separately can be examined together to provide insight into the development of sensitivity to cues to determine spatial locations in children. All components of the spatial proposition appear to contribute to its interpretation though often at different ages. The form of the predicate of the expression was significant with 'front' producing a different type of performance then 'top'. In these studies 'front' nearly always results in an intrinsic interpretation while 'top' was dependent on other constituents of the proposition.

The results of the two studies on 'top' placements indicate three age-related strategies. Each strategy is de-

termined by the attention paid to particular parts of the spatial proposition. The first strategy being used by the youngest children was to attend only to the particular object used in the relatum, meaning was assigned to the spatial terms on the basis of the object to which it was being applied. The car, for example, was almost always interpreted by its intrinsic canonical features. This could be due to young children only experiencing cars in an upright orientation resulting in their always assigning fronts and tops canonically no matter what other cues may be present. Dolls and stuffed animals are toys which children can interact with in any orientation so that the intrinsic top may be a less compelling organizational feature.

The second strategy observed only in the two groups of 5-year-olds is an indication of sensitivity to the relationship between the referent marker and the object specified in the relatum. The difference between structural and relational relationships is reflected in the children's placements in that structural relationships involve the intrinsic features of the object. This strategy is more advanced than the previous one because it involves considering two of the propositional constituents.

The third strategy, employed by the adult group in Study 1 and the two oldest groups of children in Study 2 (aged 6 and 7), was to make use of the presence of the defi-

nite article. This is the most sophisticated strategy because the influence of the form of the predicate is a subtle feature which overrides the other two constituents. It is also the most general strategy, since it does not depend on certain kinds of objects for the relatum nor certain kinds of materials for the referent. In that sense, it is an effective means of dealing with the problem of ambiguity in spatial descriptions.

Deciding on the meaning of a spatial description involves a complex evaluation of three constituents of a spatial proposition. At every step, there is the possibility for extracting multiple meanings, just as for every display, there is the possibility for assigning multiple descriptions. The development of spatial cognition involves not only the growing ability to assign such spatial propositions to complex displays, but also to use all the available information in these propositions to evaluate and interpret complex spatial descriptions. Moreover, children must learn these rules within the conventions adopted by their culture.

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FIGURE No. 1

PROPORTION INTRINSIC RESPONSES

AGE x MARKER for each object

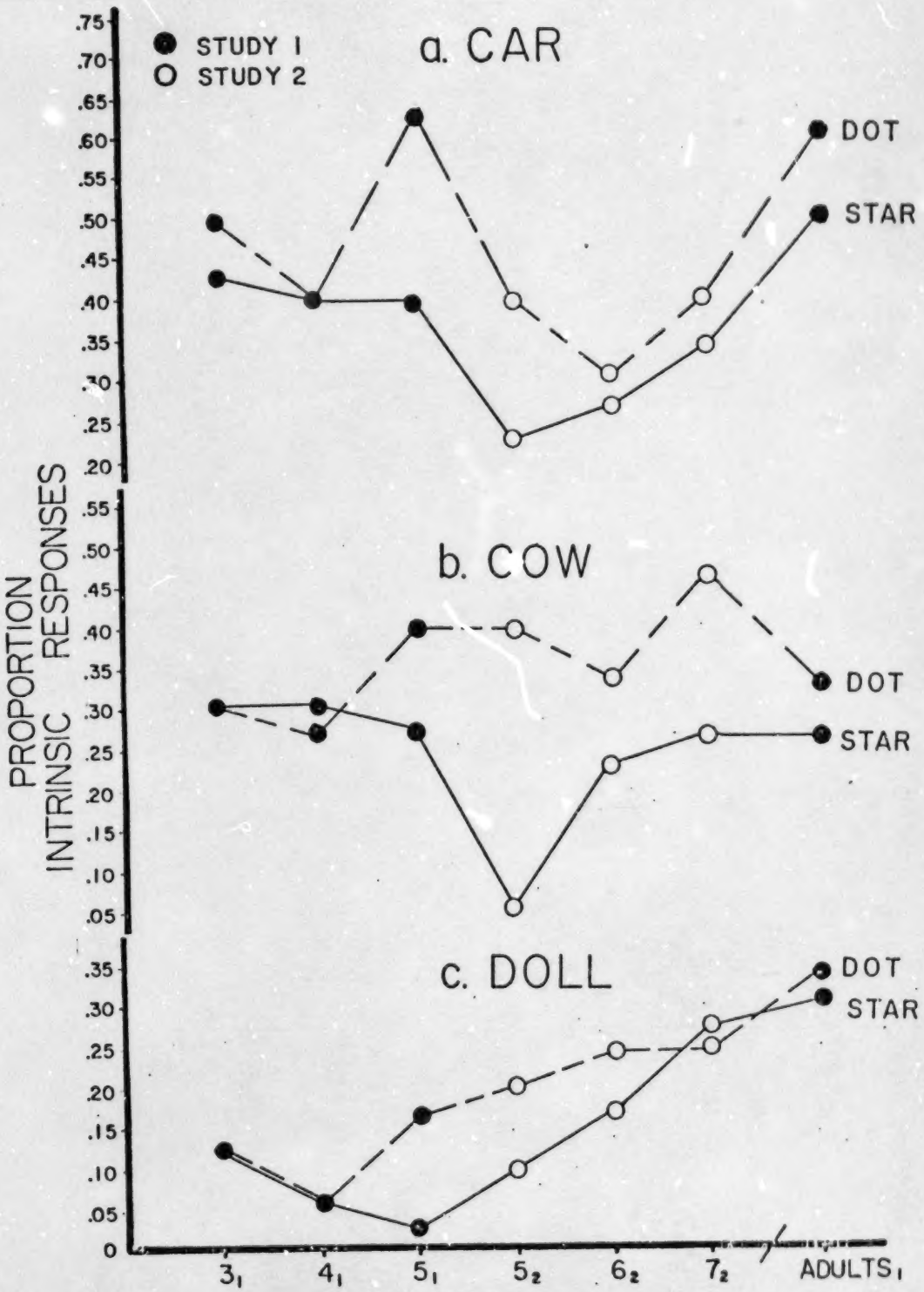

FIGURE No. 2

PROPORTION INTRINSIC RESPONSES

AGE x ARTICLE for each object